of resistance may be inherited as a dominant. However, if essential oil composition determines resistance, a lower proportion of the critical oil in the total oil content than in the case of the parent *E. maculosa* may still mean resistance, and inheritance may be still as with seedling morphological characters. If the selection of desirable segregates were possible, it would be of considerable benefit in ornamental plantings where beetle devastation is unsightly and costly to control.

In commercial planting of eucalypts on grazing lands, any means of incorporating resistance in desirable species would be of extreme importance, as it is now difficult to establish satisfactorily some of the most desirable species in heavily deforested grazing areas due to excessive beetle attack, and growth losses are often very heavy for this reason (Jacobs, 1951). There are also prospects of obtaining seed which, though not genetically uniform, may contain a high proportion of desirable combinations, and therefore which could be used effectively in rather closely spaced plantations.

The inheritance of resistance to insect attack in segregating or hybrid populations of other tree species is well enough known, for example that with Pines to Pine Weevil (Miller, 1950), and also the inheritance of resistance in susceptibility to leaf-eating insects in Poplars has been indicated.

While further experiment will be necessary to confirm the conclusions with more certainty, the evidence so far available indicates a likelihood of development in this field of study with *Eucalyptus* which may have valuable practical consequences.

## Summary.

Evidence from progeny tests and morphological analyses indicates that resistance to leaf-eating beetles in some *Eucalyptus* species is a heritable character and it appears this may assort in segregating populations independently of a number of other characters. In the re-establishment of *Eucalyptus* by planting on grazing lands where the beetle population has been very much altered as a result of tree clearing, the use of this factor by one means or another may be of critical importance for success.

*Acknowledgement.*

I am greatly indebted to Professor H. N. Barber for helpful suggestions in this study.

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## EXPLANATION OF PLATE XV.

1. Leaves, buds and fruits of the different species and hybrids. Note the three-flowered umbel on the *E. rubida* × *E. maculosa* specimen, and also a few on the *E. rubida* × *E. Macarthuri* × *E. viminalis* specimen. Note also the intermediate fruit size between the *E. rubida* × *E. Macarthuri* × *E. viminalis*. *E. Macarthuri*, *E. viminalis* types.

2. Progeny 50/724 of the supposed hybrid *E. rubida* × *E. maculosa*. Note the typical *E. rubida* form at the left, and the *E. maculosa* type at the right. Progenies approximately intermediate at the centre of the range.

3. Progeny 50/761 derived from a hybrid presumably containing *E. rubida*, *E. Macarthuri* and *E. viminalis*. *E. rubida* at the extreme left, *E. Macarthuri* in the centre and *E. viminalis* at the right, with various combinations in between.

# AUSTRALASIAN CERATOPOGONIDAE (DIPTERA, NEMATOCERA).[1]

## PART VI. AUSTRALIAN SPECIES OF CULICOIDES.

By DAVID J. LEE, B.Sc., and ERIC J. REYE, M.B., B.S.[2]

(Plate xvi; 93 Text-figures.)

[Read 26th November, 1952.]

*Synopsis.*

This systematic review of the Australian *Culicoides* comprises a discussion of the six species previously recorded from the region together with descriptions of fifteen new species, all from eastern Australia. Separation of species is primarily based on wing patterns but such other useful details as are revealed in head structures, thoracic patterns, tarsi and spermathecae are illustrated for the majority of species. A key to the identification of species is presented and a brief summary of such details of the biology of the various species as are known.



### INTRODUCTION.

The genus *Culicoides*, the dominant blood-sucking "sandfly" genus in Australia, has long been neglected. Two species were described by Skuse (1889), two by Taylor (1911 and 1918) and one by Kieffer (1917). Both of Skuse's species (*C. molestus* and *C. marmoratus*) are now well known in eastern Australia, one of Taylor's (*C. ornatus*) is well known in North Australia whereas the second (*C. multimaculatus*) has not since been collected although it is an obviously distinctive species, and the Kieffer species (*C. brevitarsis*) still remains shrouded in mystery since nothing which could be referred to this species, on the basis of the original description, has yet been recovered.

The genus occurs in all States, including Tasmania, but is apparently absent from New Zealand. It is known to occur in New Guinea but with one exception the species seen in the limited collections from New Guinea are distinct from any known to occur on the mainland of Australia. No discussion of New Guinea species is presented herein since further material is needed to clarify the characters of the few species already described from that area.

The present paper considers twenty-one species of *Culicoides*, fifteen of which are described as new. Other new species are known to occur in Australia, but there has not been sufficient material of these available to characterize them adequately and they must await further collecting.

Collections have been made in various ways, by the finger moistened with 70% alcohol for specimens actually biting or on vegetation, by suction tube, by net sweeping and by light traps. Specimens have also been recovered from animal baits and the breeding of adults from larvae or pupae has yielded others. Many have contributed to these collections but particular acknowledgement should be made of the contributions of Mr. B. McMillan, Mr. J. R. Henry, Drs. I. M. and M. J. Mackerras, Dr. F. H. S. Roberts, Mr. R. F. Riek, Dr. Elizabeth Marks and Mr. A. Dyce.

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[1] Continued from Vol. 73, page 70 (1948) of these PROCEEDINGS.

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It will be obvious that most collections have been made in New South Wales and Queensland and it is by no means unlikely, if similarly intensive collecting were undertaken in other States, that considerably more species would be disclosed.

## Method of Description.

The basic characters used in the description of species are discussed in Part I of this series (Lee, 1948). An even more recent discussion will be found in Wirth (1952).

New species have only been described when sufficient material has been available to detail those characters regarded as definitive, not only in relation to other known species, but as far as possible to furnish, in addition, sufficient detail for the ready differentiation from such other new species as may be found from time to time.

Female specimens have been selected as holotypes in all cases, this being the sex of practical importance, and as many paratypes as possible have been included in the type series. Such paratypes have almost invariably been collected with the holotype and have in part provided details which are not clear in the holotype. When male specimens have been available one of these has been selected as allotype and others as paratypes but only when the specimens concerned have some close association with the holotype or occasionally when they have come from a similar ecological environment. Otherwise male characters are given from stated specimens but these have not been included in the type series.

In all but one case the majority of the type series will be found on mounted slide specimens since this appears most practicable for subsequent checking of details not precisely discernible in pinned material. Wherever pinned specimens have been available to provide characters of coloration these have been given.

Mounted specimens have usually been prepared by clearing in phenol (saturated solution in absolute alcohol) for from one to five hours, washing in absolute alcohol and mounting in fairly thin xylol-balsam. Separation of head and one wing from the body of the specimen has often been resorted to for purposes of illustration.

Illustrations have been made with the aid of a camera lucida with the exception of those of scutal patterns where a graticule and squared paper have been used.

Primary types are all lodged in the collection of the School of Public Health and Tropical Medicine, University of Sydney (abbreviated to SPHTM in text). Where possible paratypes have also been lodged in other museums, the British Museum, London (BM in text), the United States National Museum, Washington (USNM in text), the Division of Entomology, Commonwealth Scientific and Industrial Research Organization, Canberra (CSIRO in text) and Queensland Institute of Medical Research, Brisbane (QIMR in text).

Since this is the first occasion on which reasonably detailed information on the Australian species of *Culicoides* has been presented, full distribution lists are included. These are subdivided into States and as far as possible are arranged in an approximately north to south order.

Measurements considered to be significant are included for all species. These are presented together in Table 1. In nearly all cases the holotype has been measured (except when unsuitable for reasonably accurate measurement) and as far as possible average measurements are given from a series of ten paratype specimens. If these have not been available the material measured will be found detailed in the text for each individual species.

## Genus Culicoides: Synonymy and Generic Characters.

### Genus Culicoides Latreille.

Latreille, P. A., 1809.—Genera Crust. et Insect., 4: 251.

See also:

Carter, H. F., Ingram, A., and Macfie, J. W. S., 1920.—*Ann. Trop. Med. and Parasit.*, 14: 211.

Edwards, F. W., 1926.—*Trans. ent. Soc. Lond.*, 1926: 403.

Goetghebuer, M., 1920.—*Mem. Mus. Hist. Nat. Belg.*, 8, fasc. 3: 48.

Wirth, W. W., 1952.—Univ. Calif. Pub. in Entom., 9, No. 2: 165.

*Synonymy.*—Macfie (1940) lists as synonyms the following generic names: *Oecacta* Poey 1851, *Psychophaena* Philippi 1865, *Haematomyidium* Goeldi 1905, *Cotocripus* Brethes 1912, *Haemophoructus* Macfie 1925, *Synhelea* Kieffer 1925 and *Prosapelma* Kieffer 1925. To these is added *Hoffmania* Fox in Wirth 1952.

None of these concern the Australasian region, but it should be remembered that Skuse put almost all the species he described into *Ceratopogon* and some of these are strictly species of *Culicoides.*

*Genotype*: *C. pulicaris* (Linné) (*Culex*) 1758. *Syst. Nat.*, Ed. 10., No. 3: 603.

### *Generic Characters.*

Most species of this genus are easily recognized by their spotted wings, but there are some in which the wing markings are faint or even absent and a few species in other genera with rather similar markings. However, the generally small size, the small simple claws, the lack of any pronounced modifications of the legs or of dense scale-like macrotrichia will differentiate members of *Culicoides* from species in other genera with variegated wings. Recourse to the key characters may be necessary to establish the generic identity of species lacking pronounced wing pattern.

In the head the eyes are bare and in the majority of species separated dorsally by a narrow space in the female and a rather broader one in the male. In both sexes a single long strong bristle arises between the eyes (absent when eyes are contiguous). The mouthparts are prominent and approximately as long as the height of the head in the female (relatively shorter in the male). The female palpi are five-segmented with the first, fourth and fifth segments considerably shorter than the subequal second and third segments. The latter is usually expanded with a sensory cup towards the distal end. The male palpi are similar but smaller. The female antennae have segment 1 distinct but smaller than 2 which is considerably expanded as usual; segments 3–10 are small and subequal and 11–15 are elongated; segment 15 has no terminal stylet. There are verticels of short hairs on all the flagellar segments. In the male, segment 2 is larger than in the female and only segments 13–15 are elongate. There are verticels of long hairs on segments 3–12.

The thorax has the scutum dull, sometimes mottled, with short hairs and few or no bristles. Humeral pits are always present and distinct. The legs are slender with no strong spines on femora or tarsi and no modified segments beyond a cordiform fourth tarsal segment in occasional species. The first hind tarsal segment is approximately twice or more the length of the second and the fourth tarsal segment is shorter than the fifth. The claws are small and equal in both sexes and the empodium minute.

The wings are clothed with microtrichia over the whole surface and macrotrichia are present but variable in extent. Spotting is usually but not always obvious. The branches of the radius form two cells, often rather similar to a figure eight, and the costa and $R_{4+5}$ terminate together beyond the middle of the wing. $M_2$ arises distal to r–m, although its base may be obsolete. The intercalary fork is usually distinct.

The abdomen is of only moderate length in the female but rather longer and more slender in the male. The spermathecae are usually two in number and the lamellae small and rounded.

The genitalia of the male are rather complex, the ninth tergite being large and arched over the coxites and the structures between these, and with both distal and internal processes. The highly chitinized paired harpes are often specifically variable in shape and the phallosome is in the shape of an inverted Y.

### Grouping of Species.

For the practical convenience of identification the species of *Culicoides* dealt with herein are arranged in an order which follows as closely as possible increasing complexity of wing ornamentation, this being the most readily observable character

TABLE 1.

| | | *dycei.* | *palpalis.* | *robertsi.* | *ornatus.*[1] | *molestus.*[2] | *immac-ulatus.* | *marksi.* | *subim-maculatu* |
|---|---|---|---|---|---|---|---|---|---|
| ♀♀ | | | | | | | | | |
| Wing length | Holotype | 1·02 mm. | 0·92 mm. | 0·90 mm. | 1·09 mm. | 1·35 mm. | 1·11 mm. | 1·25 mm. | 1·22 mm. |
| | Average of selected series (see text) | 0·92 mm. | 0·97 mm. | 1·00 mm. | 1·04 mm. | 1·10 mm. | 1·18 mm. | 1·21 mm. | 1·22 mm. |
| | Range in above | 0·87–0·96 mm. | 0·90–1·05 mm. | 0·90–1·08 mm. | 0·96–1·11 mm. | 1·02–1·24 mm. | 1·15–1·22 mm. | 1·09–1·32 mm. | 1·13–1·28 mm. |
| Antenna | Holotype 3–10 | 210 μ | 165 μ | 190 μ | 245 μ | 270 μ | 285 μ | 255 μ | 235 μ |
| | ,, 11–15 | 180 μ | 185 μ | 180 μ | 295 μ | 280 μ | 275 μ | 265 μ | 255 μ |
| | Average of selected series (see text)— | | | | | | | | |
| | 3–10 | 190 μ | 175 μ | 200 μ | 240 μ | 215 μ | 275 μ | 255 μ | 235 μ |
| | 11–15 | 170 μ | 195 μ | 210 μ | 290 μ | 235 μ | 300 μ | 245 μ | 255 μ |
| Palp | Holotype, segment 2 | 50 μ | 35 μ | 50 μ | 60 μ | 65 μ | 85 μ | 65 μ | 75 μ |
| | ,, ,, 3 | 45 μ | 50 μ | 35 μ | 65 μ | 85 μ | 95 μ | 60 μ | 75 μ |
| | ,, ,, 4 | 25 μ | 15 μ | 20 μ | 30 μ | 35 μ | 35 μ | 25 μ | 25 μ |
| | ,, ,, 5 | 30 μ | 20 μ | 20 μ | 25 μ | 35 μ | 25 μ | 35 μ | 20 μ |
| Hind leg | Holotype, femur | 315 μ | 305 μ | 295 μ | 370 μ | 450 μ | 435 μ | 385 μ | 395 μ |
| | ,, tibia | 295 μ | 270 μ | 285 μ | 345 μ | 450 μ | 420 μ | 385 μ | 410 μ |
| | ,, tarsus I | 140 μ | 130 μ | 130 μ | 165 μ | 230 μ | 210 μ | 190 μ | 200 μ |
| | ,, ,, II | 75 μ | 75 μ | 85 μ | 90 μ | 120 μ | 110 μ | 100 μ | 100 μ |
| | ,, ,, III | 55 μ | 50 μ | 50 μ | 55 μ | 75 μ | 75 μ | 70 μ | 75 μ |
| | ,, ,, IV | 45 μ | 40 μ | 40 μ | 40 μ | 45 μ | 50 μ | 55 μ | 45 μ |
| | ,, ,, V | 50 μ | 45 μ | 45 μ | 50 μ | 65 μ | 60 μ | 65 μ | 55 μ |
| | Average of selected series (see text)— | | | | | | | | |
| | Tarsus I | 125 μ | 140 μ | 145 μ | 175 μ | 180 μ | 230 μ | 180 μ | 190 μ |
| | ,, II | 65 μ | 75 μ | 90 μ | 95 μ | 100 μ | 125 μ | 95 μ | 100 μ |
| Spermathecae | Holotype (*a*) | | 45 × 35 μ | 35 × 30 μ | 65 × 35 μ | 40 × 35 μ | 35 × 30 μ | 35 × 30 μ | 35 × 35 μ |
| | ,, (*b*) | | 45 × 35 μ | 40 × 35 μ | 55 × 35 μ | 45 × 30 μ | 35 × 30 μ | 30 × 25 μ | 35 × 25 μ |
| | ,, (*c*) | | 10 × 10 μ | 15 × 5 μ | — | duct 20 × 5 μ | — | 25 × 25 μ | — |
| ♂♂ | | | | | | | | | |
| Average of selected series | Wing length | 0·78 mm. | 0·83 mm. | 1·01 mm. | — | — | — | 1·07 mm. | 1·43 mm. |
| | Antennal segments 3–12 | 250 μ | 280 μ | 360 μ | — | — | — | 380 μ | 395 μ |
| | Antennal segments 13–15 | 135 μ | 180 μ | 220 μ | — | — | — | 200 μ | 280 μ |

[1] Individual measurements from neoparatype.
[2] Individual measurements from specimen from Mosman, 26:i:1947.
[3] Individual measurements from specimen from Burraneer Bay, 25:xi:1950.

under most conditions of observation. Basic groupings might be proposed on a number of different aspects of the wing pattern, e.g., number of pale spots in the intercalary fork, but the one used is the one which appears to follow most closely the order of increasing complexity. This is whether or not the apical portion of cell $R_2$ is included in the pale spot which lies immediately adjacent to the termination of $R_{4+5}$.

All species described fall into one or other of two groups on this character although one, *C. robertsi*, does present some difficulty and different specimens may result in differing decisions. With this one exception which should be otherwise easily recognizable, the basic grouping appears sound. It is not proposed that this grouping is a natural one but it does serve an essentially practical purpose.

(*a*) Species in which the distal portion of the second radial cell is dark, i.e., the pale spot adjacent to the termination of $R_{4+5}$ does not include the second radial cell. Ten species are included in this group, namely, *immaculatus*, *subimmaculatus*, *palpalis*, *ornatus*, *molestus*, *marmoratus*, *mackayensis*, *rabauli*, *angularis* and *magnesianus* (Group I).